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Scientific Note

Mating Calls of Six Forms of Pelobatid in Wawu Mountain National Forest Park, Sichuan, China (Anura: Pelobatidae)

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Abstract: The mating calls of six forms belonging to four genera *Megophrys*, *Oreloalax*, *Scutiger* and *Leptolalax* were recorded in Wawu Mountain National Forest Park, Sichuan Province of China, using cassette tape recorder (Aiwa) and Sony tape with an external microphone. All recordings were analyzed with an IBM PC based "SIGNAL" software analysis system (Engineering Design, USA). The range of analyzed frequency was set as 0 - 10 kHz. Acoustic analysis shows that the dominant frequency of *L. oshanensis*, *M. minor*, *M.* sp., *S.* (*S.*) *chintingensis*, *O. omeimontis*, and *O. schmidti* is 4521.9, 3456.4, 2293.8, 1076.5, 1071.0 and 1849.4 Hz on average respectively; the note duration is 46.2, 90.8, 99.6, 72.2, 78.8 and 110.3 millisecond on average respectively; the note interval is 140.4, 253.0, 681.4, 1517.7, 461.3 and 619.5 millisecond on average respectively. One-Way ANOVA analysis indicates that there are significant differences among the analyzed six forms on the dominant frequency, the note duration, and the note interval ($P < 0.01$). Multiple comparisons using Least-Significant Difference (LSD) show that the difference of the dominant frequency between *S.* (*S.*) *chintingensis* and *O. omeimontis* is not significant ($P = 0.917 > 0.05$); on the note duration, only *L. oshanensis* is significantly different from *M. minor*, *M.* sp., *O. omeimontis* and *O. schmidti* ($P < 0.01$); on the note interval, *L. oshanensis* is not significantly different from *M. minor*, the same with *M.* sp. versus *O. schmidti* and *O. omeimontis* versus *O. schmidti* ($P > 0.05$). Correlation analysis indicates that there are no significant correlation among the three acoustic characters of dominant frequency, note duration and note interval, and two environmental factors of the elevation and air temperature ($P > 0.05$) except that the note interval is significantly linear correlated with the elevation ($r = 0.943$, $P = 0.005 < 0.01$). In the light of above, it is suggested that acoustic characteristics of calls are useful in distinguishing forms; the change of the note interval with the elevation may be a kind of strategy of reproduction.

Key words: Acoustic analysis; Mating call; *Leptolalax oshanensis*; *Megophrys minor*; *M.* sp.; *Scutiger* (*S.*) *chintingensis*; *Oreolalax omeimontis*; *O. Schmidti*

瓦屋山国家森林公园锄足蟾科6种的繁殖鸣声特性

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摘要: 在地处四川省洪雅县的瓦屋山国家森林公园录取了锄足蟾科6种的繁殖期求偶鸣叫声。它们分隶4属, 即角蟾属 (*Megophrys*)、齿蟾属 (*Oreolalax*)、齿突蟾属 (*Scutiger*) 和掌突蟾属 (*Leptolalax*)。在IBM PC上用 "SIGNAL" 软件 (Engineering Design, USA) 对获取的鸣声资料进行分析, 分析的频率范围设置为0 ~ 10

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kHz。

声学分析结果表明：峨山掌突蟾（*L. oshanensi*），小角蟾（*M. minorr*），角蟾1种（*M.* sp），金顶齿突蟾[*S.*（*S.*）*chintingensis*]，峨眉齿蟾（*O. omeimontis*）和无蹼齿蟾（*O. schmidti*）的主能峰频率平均值分别是4521.9、3456.4、2293.8、1076.5、1071.0和1849.4 Hz，每声持续时间的平均值分别是46.2、90.8、99.6、72.2、78.8和110.3 ms，声距的平均值分别是140.4、253.0、681.4、1517.7、461.3和619.5 ms。

单因子方差分析结果表明主能峰频率、每声持续时间和各声距在6个种间差异极显著（$P<0.01$）。LSD法多重比较的结果指出金顶齿突蟾和峨眉齿蟾间的主能峰频率无显著差异（$P=0.917>0.05$）；在每声持续时间上，只有峨山掌突蟾与小角蟾、角蟾1种、峨眉齿蟾、无蹼齿蟾间差异极显著（$P<0.01$）；在声距上，峨山掌突蟾与小角蟾间无显著差异，角蟾1种与无蹼齿蟾之间、峨眉齿蟾与无蹼齿蟾之间也是如此（$P>0.05$）。

简单相关分析结果表明3类鸣声性状即主能峰频率、每声持续时间和声距与2类环境因素即海拔高度和气温间无显著的相关关系（$P>0.05$），只有声距（*NI*）与海拔高度（*E*）有极显著的线性相关关系（$NI=-669.130+0.802E$，$r=0.943$，$P=0.005<0.01$）。我们对结果进行分析和讨论认为，蛙类繁殖鸣声特性在识别或区分物种类群上是有用的，鸣声声距随海拔改变可能是一种繁殖策略。

关键词：鸣声分析；繁殖鸣声；峨山掌突蟾；小角蟾；角蟾1种；金顶齿突蟾；峨眉齿蟾；无蹼齿蟾
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The vocalization of frogs is one important biological characteristic and the mating call of male frogs is the medium on which the frogs conduct their reproductive activity. There are distinguished characteristics of the mating call in different species (Dring, 1983; Heyer, 1984; Inger & Dring, 1988; Matsui, 1997; Matsui & Wu, 1994; Matsui *et al.*, 1993), but the characteristics are sometimes present difference within a species from different localities, i.e. "dialect" (Jiang *et al.*, 1995; Schneider & Egiasaryan, 1995).

There are a few reports about the vocalizations of frogs from China, such as Huang *et al.* (1982), Jiang *et al.* (1995), Mou & Zhao (1992), Matsui & Wu (1994), and Matsui *et al.* (1993). The forms presented in these reports included some of Discoglossidae, Bufonidae, Hylidae, Ranidae, Rhacophoridae, and Microhylidae, while those excluded Pelobatidae.

The purpose of this report is to describe the acoustic characteristics of the mating calls of six spaded toad. As is a contribution to our knowledge of spaded toad vocalizations in general but also to point out the peculiar nature of their mating calls.

1 Materials and Methods

The calls of the six forms were recorded in the field during their mating season using cassette tape recorder (Aiwa) and Sony tape with an external microphone (Aiwa) from 19:00 to 21:00 in Wawu Mountain National Forest Park, Sichuan, China. Information related to the recorded calls is summarized in Table 1.

Table 1 Information related to the recorded calls

Form	Specimen No.	Recorded date	Locality	Elevation (m)	Air temperature (℃)
Leptolalax oshanensis (Liu)	CIB950034	May 12, 1995	Binglng	1 100	14
Megophrys minor Stejneger	CIB950258	June 20, 1995	Jinhuaqiao	1 200	14
M. sp.	CIB950322	May 26, 1995	Xijuegou	1 800	13
Scutiger (*S.*) *chintingensis* Liu *et* Hu	CIB950216	May 25, 1995	Yangxi	2 550	12
Oreolalax omeimontis (Liu et Hu)	CIB950013	May 11, 1995	Laugou	1 100	17
O. schmidti (Liu)	CIB950162	May 23, 1995	Xijuegou	1 840	14

The calls were analyzed using an IBM PC based "SIGNAL" software analysis system (Engineering Design, USA) in Institute of Hydrobiology, the Chinese Academy of Sciences. The range of analyzed frequency was set between 0 – 10 kHz. Sonograms were produced with a frequency resolution of 49 Hz. Three variables of dominant frequency, note duration and note interval were measured. Data were analyzed using One-Way ANOVA, Correlation and Regression Program of SPSS package (Lu *et al.*, 1999).

Terms used to describe calls are below. ①call: a series of notes; ②note: a group of pulses; ③note duration: the time from beginning of the first pulse to the end of the last pulse in one note; ④note interval: the

time from the beginning of one note to the beginning of the next note; ⑤note repetition rate: the number of notes per second; ⑥dominant frequency: the frequency of a higher power peak presenting in the power spectrum; ⑦power peak: the peak present in the power spectrum.

2 Results

2.1 Acoustic characteristics

The waveform, audio-spectrogram, and power spectrum of the mating calls of the six forms analyzed are comprehensively presented in Figs.1 – 6. Five acoustic characters, dominant frequency, note duration, note interval, note repetition rate, and number of power peak, are summarized in Table 2.

Calls of *L. oshanensis* consist of a series of 20 more notes given at a rate of 7 notes per second. The calls have very rapid attack times (Table 2). It looks like a three-note-unit repeated frequently (Fig.1A). As seen in the audio-spectrogram (Fig.1B) and power spectrum (Fig.1C), there are two distinct power peaks that are being broadcast, the dominant one is present at 4 521.9 ± 79.6 Hz, the second peak of energy at about 8 800 Hz.

Table 2 Five acoustic characters of the mating call of the six forms

Form	Dominant frequency (Hz)	Note duration (ms)	Note interval (ms)	Note repetition rate	No of power peak
L. oshanensis	4521.9 ± 79.6	46.2 ± 12.9	140.4 ± 53.9	7	2
	4402 – 4633	28.6 – 66.7	85.7 – 219		
	(n = 10)	(n = 13)	(n = 12)		
M. minor	3456.4 ± 22.8	90.8 ± 12.6	253.0 ± 35.8	4	2
	3424.1 – 3497.3	74.6 – 110.1	212.8 – 363.1		
	(n = 10)	(n = 14)	(n = 14)		
M. sp.	2293.8 ± 149.5	99.6 ± 14.4	681.4 ± 101.4	1.7	2
	2105.7 – 2508.5	82.0 – 133.8	505.0 – 849.5		
	(n = 13)	(n = 14)	(n = 11)		
S. (S.) chintingensis	1076.5 ± 93.9	72.2 ± 21.2	1517.7 ± 881.8	0.75	1
	979.6 – 1254.3	51.8 – 94.1	894.1 – 2141.2		
	(n = 10)	(n = 3)	(n = 2)		
O. omeimontis	1071.0 ± 42.8	78.8 ± 18.2	461.3 ± 32.0	2	1
	961.3 – 1101.7	40.2 – 96.4	401.5 – 505.9		
	(n = 10)	(n = 11)	(n = 10)		
O. schmidti	1849.4 ± 112.7	110.3 ± 99.7	619.5 ± 49.6	2	3
	1724.2 – 2072.1	25.3 – 226.7	573.3 – 672.0		
	(n = 10)	(n = 4)	(n = 3)		

n: Number of analyzed notes.

Calls of *M. minor* consist of about 8 – 16 pulsed notes (Fig.2A). The calls have a medium rapid attack times with a rate of 4 notes per second (Table 2). There are two power peaks (Fig. 2C) present at 3 456.4 ± 22.8 and about 7 200 Hz.

Calls of *M.* sp consist of 2 – 5 pulsed notes (Fig.3A). and the call has a slow attack times with a rate of 1.7 notes per second (Table 2). The notes also have two power peaks (Fig.3C) present at 2 293.8 ± 149.5 Hz and about 5 000 Hz.

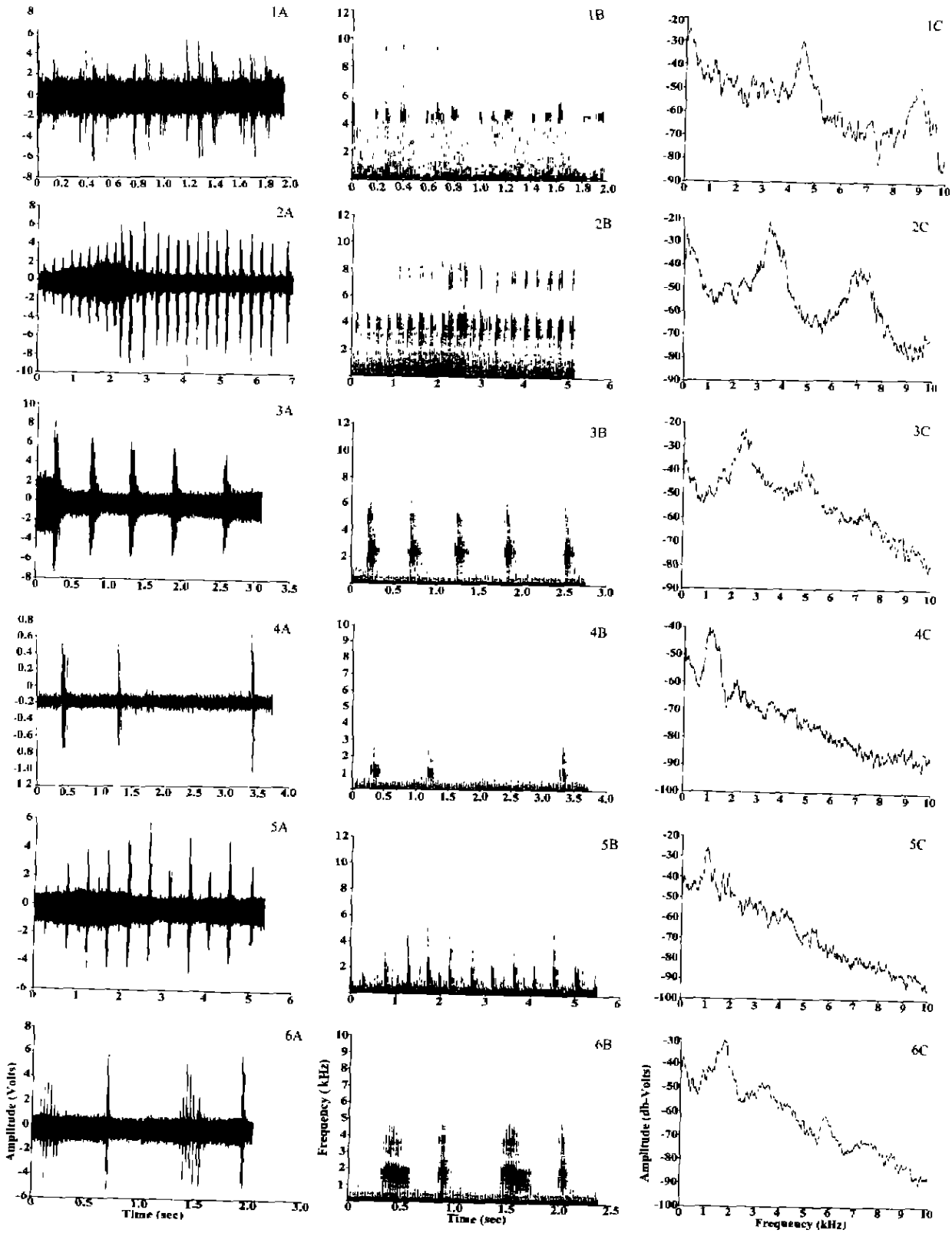
S. (S.) chintingensis have calls consisting of 3 – 10 notes given at a rate of 0.75 notes per second. Their calls have a very slow attack times. There is only one band of energy that is being broadcast at 1 076.5 ± 93.9 Hz (Fig.4C).

Calls of *O. omeimontis* consist of single note given at a rate of 2 notes per second. As seen in the audio-spectrogram (Fig.5B) and power spectrum (Fig.5C), there is only one band of energy that presents at 1 071.0 ± 42.8 Hz.

Calls of *O. schmidti* consist of two notes given at a rate of 1 call per second (Fig.6A), and is a two-note-unit repeated frequently. It has three power peaks present at 1 849.4 ± 112.7 Hz, about 3 400 Hz and 6 000 Hz (Figs.6B, 6C).

2.2 Comparisons of acoustic characters

The results of One-Way ANOVA proceeding of Compare Means in SPSS Package show that the dominant frequency are significantly different among the analyzed six forms ($P < 0.01$), the same with the note du-



Figs. 1 – 6 The waveform (A), audio-spectrogram (B), and power spectrum (C) of mating calls of the six forms
1. *L. oshanensis*; 2. *M. minor*; 3. *M.* sp.; 4. *S.* (*S.*) *chinlingensis*; 5. *O. omeomonts*; 6. *O. schmidti*.

ration ($P < 0.01$) and the note interval ($P < 0.01$). The results of multiple comparisons using LSD show that on the dominant frequency, *S.*(*S.*) *chintingensis* is not significantly different from that of *O. omeimontis* ($P = 0.917 > 0.05$); on the note duration, only *L. oshanensis* is significantly different from *M. minor*, *M.* sp., *O. omeimontis* and *O. schmidti* ($P < 0.01$); on the note interval, *L. oshanensis* is not significantly different from *M. minor* ($P > 0.05$), the same with *M.* sp versus *O. schmidti* ($P > 0.05$), and *O. omeimontis* versus *O. schmidti* ($P > 0.05$). This suggests that the acoustic characters are firmly useful in identifying different forms presented in this paper, but some forms are not distinguished by one character of acoustics. Since the numbers of individuals and populations each forms are limited, the conclusion needs further being testified.

2.3 Relationships between acoustic characters and environmental factors

On the basis of Table 1 and Table 2, the correlations between three acoustic characters of the dominant frequency, note duration and note interval, and two environmental factors of the elevation and air temperature were analyzed using Correlate Program of SPSS. All correlations are not significant, except that the note interval (NI) is significantly linear correlated with the elevation (E), i.e. $NI = -669.130 + 0.802E$ ($r = 0.943$, $P = 0.005 < 0.01$).

3 Discussions

3.1 The taxonomical status of *M.* sp.

A mating call is an important medium of mate recognition in anurans (Arak, 1983), and changes of their acoustic characteristics usually lead to a starting of new adaptation and further lead to reproductive isolation. So it is useful for elucidating taxonomic problems (Matsui, 1997). This conclusion is also upheld by the results of this paper.

The acoustic analysis shows that there are significant differences between *M.* sp. and *M. minor* both on the note interval and dominant frequency ($P < 0.01$). In addition, the sub-dominant frequency of *M.* sp. (4 800 – 5 100 Hz) is distinctly different from that of *M. minor* (6 800 – 7 600 Hz). These indicate that there are apparent differences on the signals of mating recognizing system between them, that is to say a reproductive behavior has presented isolation between them, so it is inferred that *M.* sp. and *M. minor* may be different species. However, the final determination of taxonomical status of *M.* sp. needs further researching morphological data and extending the taxa range of comparison.

3.2 Relationships among *L. oshanensis* and Malaysian *Leptolalax*

Matsui (1997) reported the call characteristics of five forms of the genus *Leptolalax* from Malaysian, *L. heteropus*, *L. gracilis*, *L. dringi*, *L.* sp.1, and *L.* sp.2. The later two of them were described as new species, *L. hamidi* and *L. arayai*, on the basis of acoustic and morphological comparisons. The feature of three-note-unit repeated frequently in call are found both in *L. oshanensis* (Fig. 1A) and *L. heteropus* (Matsui, 1997). Comparing the acoustic characteristics of species in the genus *Leptolalax* reported by Matsui (1997) and this study, it is found that there are the similar note duration (mean 29 – 80 ms) and note interval (mean 89 – 140 ms). This indicates that calls of the six forms of *Leptolalax* have very rapid attack times, which may be a common feature of the genus. These six forms of *Leptolalax* can be distinguished by their dominant frequencies.

3.3 Relationships between the note interval and elevation

It is showed in the present paper that the note interval is significantly linear correlated with the environmental elevation. This may show an important strategy of reproduction. In breeding seasons, the male's calling is to attract the female so that they can successfully mate. The calling demands energy that is produced from food's being oxidized *in situ*. Oxidation demands oxygen provided by oxyhemoglobin that is produced from respiration. We know that the higher elevation, the lower air pressure and oxygen denseness, and the more difficult respiration. The longer the note interval, the smaller the oxygen demanded within a call. So the change of the note interval with the elevation is a kind

of strategy of reproduction, also a kind adaptation to environment.

Two problems are remained to further study. One is to further test the relationships between the not interval and the elevation found in this paper, the another is to further study the mechanism that anuran calling adapt to the elevation.

3.4 The feature of reproductive isolation

Six forms are analyzed in this paper. Of them, *O. omeimontis*, *O. schmidti*, and *S.(S.) chintingensis* belong to related genus. The later two species are both found at the top of Wawu Mountain, i.e., sympatric, while the first one is found at Liugou 60 km far from the later two. The differences of acoustic characteristics of the mating calls between the later two species are more than those between *O. omeimontis* and *S.(S.) chintingensis*, especially the dominant frequency and power spectrum (see Table 2 and Figs.4-6C). This proves a conclusion that, among related forms, the reproductive isolation between sympatric species is more apparent or strict than that between non-sympatric species.

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